MODELING LATE QUATERNARY VEGETATION DYNAMICS IN EASTERM MARAJÓ ISLAND (NORTHERN BRAZIL): A MULTIDISCIPLINARY APPROACH

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An important step on modeling the Amazonian biodiversity is the identification of the main environmental parameters with the highest functional control on species occurrence. A variety of hypotheses have been formulated, in special regarding geologic parameters (*e.g*., Van der Hammen *et al*., 1992; Freitas *et al*., 2001; Haffer, 2001; Haffer & Prance, 2001; Patton & Silva, 2001), but all of them remain open for debates and must be tested within a larger volume of observational data. One of the major problems to evaluate environmental influences on the distribution of Amazonian plant species, is the overall scarcity of detailed information concerning to both geology and geomorphology that might determine soil properties, including mineralogy, texture, humidity and nutrient content.

Floristic survey integrated with terrain characterization undertaken was undertaken to help discussing the main controls on distribution of vegetation types in Marajó Island. In particular, the processes leading to the intriguing coexistence of large areas of savannas and wet lowland forests have been not discussed for this locality yet. There are many other occurrences of patches of savannas in Amazon region. These have been attributed to either modern climate changes at a local scale or as remnants of a vegetation cover formed under influence of the last maximum aridity during the Younger Dryas (Ledru, 2002; Ledru *et al.,* 2006). Whatever the origin, it has been proposed that the maintenance of large savanna areas in eastern Marajó might be a response to a favorable geological setting characterized by a slightly progressive tectonic subsidence and/or relative sea level rise, which would have kept the area under influence of flooding through Holocene (Rossetti & Toledo, 2006).

This scenario seems to be still going on, as revealed by numerous paleochannels that became, or is in the process of become, abandoned in Marajó landscape. As previously mentioned, the paleochannels formed due to diversion of the lower course of paleo-Tocantins River from NNW to ENE (Rossetti & Valeriano, 2006). The hypothesis proposed herein is that this evolutionary history, rather than soil fertility, was the main factor to determine the sites for establishment of vegetation types in eastern Marajó Island. This is suggested with basis on the recognition of a systematic association of vegetation types displaying arboreal composition with paleochannels.

The goal of this paper is to discuss the dynamics involved on Amazonian vegetation development within the context of changing landscapes as reconstructed from Quaternary geologic processes. The data used in this instance derive from eastern Marajó Island located at the mouth of Amazon River, where a mosaic of savanna and forest vegetation is present in contrast to the western side of the island, where lowland dense forest vegetation is present. Understanding the relationship amongst these contrasting vegetation patterns, particularly between them and the substratum in this area, is of high relevance to: 1. provide elements for approaching the origin of similar vegetation structures in other Amazonian areas; and 2. contribute for identifying environmental variables of relevance to be included on models aiming to analyze the Amazon biodiversity.

The study was based on a multidisciplinary approach integrating floristic analysis, terrain morphology, sedimentology, and $\delta^{13}C$ of organic matter from soil profiles. The floristic analysis consisted of rapid ecologic assessment (REA, Sayre et al., 2000) of 33 studied observation points, with data analized to determine occurrence, specific richness, hierarchical distribution and matrix of floristic similarity between pairs of vegetation types. Terrain characterization was based on the analysis of Landsat images using a 4(R), 5(G), 7(B) composition, added to analysis of digital elevation data obtained from Shuttle Radar Topographic Mission (SRTM). Sedimentological studies consisted of field descriptions of sediments in surface and cores. The study was completed with radiocarbon dating and analysis of $\delta^{13}C$ of organic matter from soil profiles comparing natural ecotone forest-savanna. Core samples were collected in every 10 cm of depth, reaching maximum depths of 3.30 m in point 4 and 2.10 m in point 3. Dominant plant species around these sampling points were collected and identified to complete this study.

Our integrated study of remote sensing interpretation and fieldwork mapping led to the recognition that changes in the physical environment, rather than climate variation (uniform in this area), have determined the distribution of vegetation types in the study area. The majority of the belts containing wet lowland forest vegetation, as well as woodland and woodland-bush savannas, is related to geomorphologic features attributed to paleochannels. This is mostly due to slightly higher (in general, 2-3 m) reliefs over paleochannels, which keep them protected from seasonal flooding. On the other hand, grassland-shrubland savannas are systematically developed on flat and, in many instances, slightly lower lying areas adjacent to these features. In general, the contact between these vegetation types is sharp, but there are also many places where a transitional zone exist between them, where several species from forested paleochannels are present, progressively decreasing in volume toward open areas. Finally, woodland savanna was recorded only locally in areas where a lateritic paleosol at the top of Barreiras Formation is exposed at or is near surface. Given these relationships, characterization of these geomorphologic features, as well as understanding their origin and evolution, seem to be critical to discuss both time and mode of plant colonization in eastern Marajó Island.

The results presented here show that, rather than climate or soil nutrient, the modern floristic distribution in eastern Marajó Island was controlled by changes in the depositional settings through time. Climate remains fairly constant throughout the area, despite the high degree of biodiversity changes at any scale from alpha to gamma diversity. This area might have had even more widespread non-vegetated or open vegetated areas than today by the time the channels were active, i.e., in early Holocene. As channels became progressively abandoned, as a result of tectonics and probably due to the presence of a drier climate than the previous period, they were filled with sediments, mostly sands. The sand bodies acted as freshwater reservoirs, and also stood slightly up in the landscape, eventually remaining above water level even during raining seasons, configuring substrates favorable for tree growth. Areas where channel abandonment took place earlier display denser vegetation cover than paleochannels abandoned more recently. If this model is correct, than one can state that areas with open vegetation in eastern Marajó decreased in size since the channels were active. As these features are progressively abandoned, there has been invasion of arboreal species, probably derived from the western side of the island. Considering the continuity of this process, on could predict that the wet lowland forest that dominates to the west will amplify eastwards in the near future.

Stable carbon isotope composition ($\delta^{13}C$) of soil organic matter further supports the above proposed model, showing that the study area changed from forest (C3 plants) into savanna (C4 plants) in the last thousand years, which was followed by a forest expansion, a process that is progressively taking place eastwards. A similar pattern of forest expansion on savanna areas in the last 4,000 yrs B.P., as recorded herein, has been recorded in other localities in Brazil (Freitas *et al*., 2001; Pessenda *et al*., 1998, 2001).

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